Micro-hydro Summary

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Prepared by Luke Hutchinson, Linkd Environmental Services
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1. Introduction

Hydropower is the means of using the flow of water, which is moving due to gravitational force to drive turbines that generate electricity. The scale of installation can vary from as little as a few kilowatts to hundreds of megawatts. Hydropower may include tidal and wave technologies, however this will not be covered in this technology review.

Today, the development of large scale hydro operations is not preferred and resisted due to the potential for upstream flooding which can destroy agricultural areas, animal habitats and displace communities in the affected areas\(^1\). Micro-hydro presents an alternative option with environmental impact on a far minimal scale because implementation is possible coupled to other uses of water (e.g. bulk water supply, irrigation, flood control, etc)\(^2\).

Micro-hydro power plants, involving small dams, pumps or water mills, can provide a means of electricity to communities that cannot be connected to the national grid. With capacity of 10 kW to 10 MW the technology can provide electricity in remote areas in a very effective way with a lifespan of 30 years or more. Furthermore, it is estimated that for every 1 MW of hydropower installed, two permanent jobs are created in the hydropower industry\(^2\).

Internationally no size terminology is standardised, the following is an indication\(^2\):

- **Pico** less than 20 kW
- **Micro** 20 kW to 100 kW
- **Mini** 100 kW to 1 MW
- **Small** 1 MW to 10 MW

Macro hydro conventional installations: greater than 10 MW. For general purposes micro-hydro will be used to refer to generation less than 10 MW.

2. Technical Overview

A fundamental design requirement for economic sustainability is the efficient use of the water resource. Modern turbine technology will allow up to 95% of the energy available from water to be converted into electricity\(^3\).

The power output of a hydropower plant is proportional to the water flow rate and the head (the height through which the water must descend before going through the turbine). The flow rate is the quantity of water flowing past a point in a given time - typically measured in litres per second or cubic metres per second. The head is the vertical height, in metres, from the turbine to the point where the water enters the intake pipe or penstock.

The potential power can be calculated\(^4\) as follows:

\[
\text{Theoretical power (P)} = \text{Flow rate (Q)} \times \text{Head (H)} \times \text{Gravity (g)} = 9.81 \text{ m/s}^2
\]

When Q is in cubic metres per second, H in metres and g = 9.81 m/s\(^2\) then, \(P = 9.81 \times Q \times H \text{ (kW)}\)

However, energy is always lost when it is converted from one form to another. Power will be lost in the penstock carrying the water to the turbine, due to frictional losses. With careful design, this loss can be reduced to only a small percentage.

Example: A turbine generator set operating at a head of 10 metres with flow of 0.3 cubic metres per second will deliver approximately, \(9.81 \times 0.5 \times 0.3 \times 10 = 18 \text{ kW}\).

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\(^1\) Department of Energy Philippines - http://www.doe.gov.ph/ER/Hydropower.htm

\(^2\) Baseline Study: Hydropower in South Africa, Department of Minerals and Energy, Capacity Building in Energy Efficiency and Renewable Energy (CaBEERE) - 2002

\(^3\) H Erdmannsdörfer, Small Decentralized Hydropower Stations- A Future for Rural Areas without Diesel Power, Germany-Energy Partner for Africa
The type of energy conversion technology required is related to the head classification. Hydro power conversion occurs through the use of either impulse or reaction turbines. Impulse turbines convert the kinetic energy while reaction turbines convert the pressure energy into mechanical energy. Reaction turbines work by fully immersing the turbine blades in water and must be built to withstand the operating pressure, turbine examples include Francis and Kaplan turbines. Impulse turbines make use of a high-speed jet of water striking the buckets making use of the water's motion, turbine examples include: Pelton, Turgo, cross-flow turbines.

**Figure 1 – Types of turbines, reaction at left, impulse at right.**

### 2.1 Configuration Options

**Run-of-river**

The majority of micro-hydro power plants are run-of-river schemes. This type of hydro power plant operates under low head and is mainly built in river valleys. Electricity is only generated when water is available and will stop if the flow falls below a certain level. As a result small independent schemes may not always be able to supply electricity, unless they are sized so that there is always sufficient water.

The main components of a run-of-the-river micro-hydro scheme are shown in the illustration below. This type of setup requires no water storage but instead diverts some water from the river along the side of a valley to be ‘dropped’ into the turbine via the penstock. There are various other configurations which can be used depending on the topographical and hydrological conditions, but all adopt similar general principles and methodologies.

**Figure 2: Layout of a typical micro hydro scheme**

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1 Online resource - http://www.hydro-turbines.com/id74.html
2 Micro-hydro Power, Practical Action – Technology Challenging Poverty
Dam walls

Dam wall hydropower schemes are usually not implemented for small or micro-hydro due to financial constraints, however; this configuration is viable if such dams have already been constructed. The main issue is how to link headwater and tail water by a waterway and how to fit the turbine in this waterway. The two configurations in this case are to place the turbine at the base of the dam if a channel can be constructed, the alternative is a siphon intake as shown below.

![Diagram of siphon intake configuration with the turbine placed at the apex of the siphon.]

Figure 3. Siphon intake configuration with the turbine placed at the apex of the siphon.

Water Infrastructure

In some instances there is the opportunity to harness the energy contained in the bulk water supply and distribution system, one example is constructing a hydropower facility within irrigation canals. Another option is to integrate a turbine into the drinking water infrastructure between reservoir and the water treatment plant. In some cases plants have special valves to dissipate the kinetic energy and there is an opportunity to convert this energy into electricity.

6 Guide on How to Develop a Small Hydropower Plan – ESHA 2004
3. Local Potential

The hydropower potential has been shown in the “Baseline Study on Hydropower in South Africa” (CaBEERE, 2002 – an assessment conducted by the DME) that there exists a significant potential for development of all categories of hydropower in the short and medium-term in specific areas of the country. The image below shows all areas with hydro potential and it is evident that the Eastern Cape and KwaZulu-Natal provinces hold significant capacity – and notably, with the best potential for the development of small, hydropower (less than 10MW).

Furthermore, the Eastern Cape province (particularly in the area of Transkei) is identified as potentially the most productive areas for hydro-electric development in South Africa. Investigating the potential in the Lower Orange river for hydropower setup in series or tandem, shows that some 12 hydro-electric plants can be installed in series, each site having a potential output of between 6MW and 25MW\(^7\). Table X shows the available and potential of hydropower in South Africa.

Another study indicates that there are 3500 – 5000 potential sites for mini/micro hydro electric power plants identified along the eastern parts of the country\(^8\).

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\(^7\) Clackson, E. (2002). Refurbishment and upgrading of existing hydro-power installations. Personal communication, Nelspruit, Mpumalanga, July

\(^8\) B Barta, Hydropower Potential in Southern Africa, Traders Issue 20, November 2004- February 2005
Table 1: Total for macro and small hydropower in SA - excluding pump storage (CaBEERE, 2002).

<table>
<thead>
<tr>
<th>Province in South Africa</th>
<th>Installed capacity</th>
<th>Present production (GWh/a)</th>
<th>Firm development potential</th>
<th>Possible production (GWh/a)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Small (&lt;10MW)</td>
<td>Large (&gt;10MW)</td>
<td>Load factor</td>
<td>Small (&lt;10MW)</td>
</tr>
<tr>
<td>Northern Cape</td>
<td>1,8</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Western Cape</td>
<td>0,3</td>
<td>0,25</td>
<td>neg</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Eastern Cape</td>
<td>2,5</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Free State</td>
<td>3,2</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>North-West</td>
<td>600</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>KwaZulu Natal</td>
<td>1,8</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Mpumulanga</td>
<td>0,3</td>
<td>0,25</td>
<td>neg</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Gauteng</td>
<td>0,6</td>
<td>0,25</td>
<td>neg</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Limpopo</td>
<td>0,6</td>
<td>0,25</td>
<td>2</td>
<td>0,75 to 1</td>
</tr>
<tr>
<td>Total SA</td>
<td>33,9</td>
<td>653</td>
<td>Varies</td>
<td>721</td>
</tr>
</tbody>
</table>

Job Creation

The short-to medium-term possible hydro-electricity production is estimated at some 450 GWh/year, depending on the load factor adopted. The medium-term potential for job creation only from the development of micro hydropower schemes is estimated at about 3,000 jobs, with some 1,100 jobs on a permanent basis in the operation, manufacturing and administration of hydropower development.

Due to the presence of sizable and established mining industry in South Africa, there is a large industrial support base capable of providing needed expertise for manufacture, servicing and refurbishment of essential hydropower products for the development of small hydropower systems. It is estimated that for every 1 MW of hydropower installed, two permanent jobs will be created in the hydropower industry.

4. Regulatory Framework

Irrespective of the size of installation, any hydropower development will require authorisation in terms of the National Water Act 1998, Act 36 of 1998. The act stipulates the necessity to register a Water Use License, and the following entities are required to register:

- Individuals – such as farmers, small-holders, land-owners or lessees.
- Communities – such as communal enterprises, traditional farmers groups.
- National or Provincial Government.
- Companies and businesses – including partnerships, public companies, private companies, companies not for gain, guarantee companies, foreign companies, incorporated private companies, closed corporations etc.
- Water User Associations.
- Water Services Providers, including Water Boards and Local Government.

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9 Baseline Study: Hydropower in South Africa, Department of Minerals and Energy, Capacity Building in Energy Efficiency and Renewable Energy (CaBEERE) - 2002

Registration does not setup entitlement to use the water, the water use license authorises proponent to use water. Registration should be seen as the first step in establishing a relationship as a water user with the Department. Forms to register are obtainable from any office of the Department. Registration cannot be turned down or denied, if the water use is of a legitimate means.

The following is a basic outline of the processes to obtain a water use license:\n
- Applications are obtained and submitted to DWAF regional offices.
- The regional office will assess the applications and advise on the requirements. The Regional office will further make a recommendation to the delegated official.
- The regional office will then submit the application to the Head Office: Chief Directorate: Water Use for further handling.
- The Chief Directorate: Water Use will review the license application for compliance with the Policy
- The Chief Director: Water Use will then make recommendations for the Minister to make a decision.
- Applicants may appeal the decisions to the Water Tribunal.

For more detailed information refer to “A Guide to the Registration of Water Use Under the National Water Act (Act 36 of 1998)” and see the instructions at www.dwaf.gov.za/Projects/WARMS

5. Barriers to Implementation

The many challenges facing small hydropower exploitation are generally shared barriers of renewable energy industry and independent power producers. These barriers are the lack of clear and consistent policies on renewable energy and associated requisite budgetary allocations to create an enabling environment for mobilising resources and encouraging investment. Furthermore, the absence of low-cost, long-term financing models to provide renewables to customers at affordable prices while ensuring that the industry remains sustainable exasperates development.

Micro-hydro faces the following specific issues:\n
- Limited access to appropriate technologies, with special technical challenges due to the local context of small heads and high volumes or very high heads and low volumes.
- Limited infrastructure in the field’s of manufacturing, installation and operation. Even the most rudimentary turbines or parts that are critical to maintenance have limited manufacturing support on the continent. An example is the un-available capacity to manufacture high-density polyvinyl pipes that can serve as good penstocks - few countries have these products and as a result implementation at simple sites has been hampered. (However, due to the presence of the mining industry in South Africa, there is a large industrial support base in existence, capable of providing the needed expertise for manufacture, servicing and refurbishment of essential hydropower products, which is primarily mining-type equipment.)\n
- Limited capacity to design and develop micro-hydro for areas sometimes considered too remote. Generally, South Africa has limited capacity of experts to undertake micro-hydro feasibility studies.
- The regulatory administration issues required for the Water Use License. (The Department of Water Affairs is said to have a strategy to guide the project development of hydropower).

The micro-hydro experience in the Philippines is that off-grid electrification is hindered by high upfront costs and the need for government intervention and subsidy.

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12 Small hydropower for rural electrification in South Africa - using experiences from other African countries, Klunne - CSIR 2009
13 Baseline Study: Hydropower in South Africa, Department of Minerals and Energy, Capacity Building in Energy Efficiency and Renewable Energy (CaBEERE) - 2002
14 Department of Energy, Philippines - www.doe.gov.ph/ER/Hydropower.htm
Government have established the Working for Energy programme which welcomes project developers interested in providing sustainable energy solutions to rural communities, using specifically micro-hydro. More information at www.reee.sacities.net/resources/wfe.htm